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The Mechanics of Lateral Curvature.

BY

HENRY O. FEISS, M. D.,

Cleveland.

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THE MECHANICS OF LATERAL CURVATURE.

First Paper: The Mechanical Tendencies of Posture in the Normal.

HENRY O. FEISS, M. D., CLEVELAND.

In this report we are investigating the laws of the tendencies resulting from postural attitudes, the work being a preliminary part of a study of the mechanics of lateral curvature. (The investigation of the mechanical relation of normal posture to scoliosis has very recently been advanced by Dr. Lovett and it is from this work that we get the clew to further study.)

Segmentation and Balance.

In all erect attitudes some effort is necessary to enable a person to stand alone and this effort is afforded by muscular power, but there are certain positions in which the muscular power may be reduced to a minimum and these are obtained by distributing the weight uniformly about a perpendicular line which passes through the center of gravity. (Parow, Horner.)

The body is, however, not a firm mass but consists of segments jointed together, one segment resting upon the other. To prevent the body from collapsing connection between segments must be rendered firm. This is done by tightening the tube of tissues connecting superimposed ones. Then to maintain the erect attitude the line of gravity must pass through the base of support. So in all postures in which balance is maintained there is a constant equilibration by means of shifting segments. (Rimmer, Herman.)

But whether for the sake of balance or not, the result of this segmental movement must mean that the tube of soft parts made

up of muscles, fasciæ and integument, and joining adjacent segments is subject to a constant change to tension, so that if one segment moves upon an underlying one, the fact that motion takes place means that the soft parts which connect them must be in greater tension on some sides than on others. So again in the maintenance of an erect attitude which is asymmetrical the tube of soft parts is subject to difference in tension in accordance with the amount of shifting of superimposed segments. In a word, the attainment and maintenance of all positions entails a firm tonicity and tension in those parts of the body in which the segments are most separated. (Zuckerkandl and Erben, Duchenne, Spencer.)

The Movements of the Spinal Column With the Thorax.

If we regard this part of the skeleton in its ligamentous state any motion of the dorsal column must imply a motion of the thorax, for although the spine by itself is an elastic column, its intimate connection with the thorax must give that part of the column a relative unity of action. In the first place the attach-

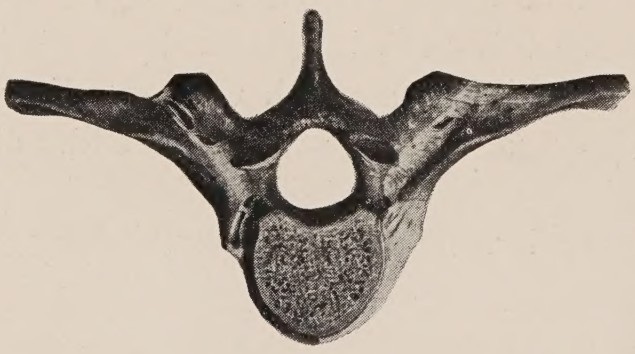

Fig. 1. Fick. The attachment of the ribs to a vertebra, seen from above.

ment of separate ribs is of such a nature as to render a movement of any one of the upper ten vertebræ impossible without carrying with it a rib, for each of these ribs is attached to a vertebral body and to its transverse process. (Fig. 1.) As each is also attached to the sternum by means of a firm cartilage, then a movement of a rib must imply a movement of the sternum, which again implies

movement of all the ribs attached thereto, for the sternum completes the thoracic basket anteriorly and establishes its unity. The nature of the separate rib attachment to the vertebral bodies is suggestive from another point of view, for the upper ten on each side are attached not to one body but to two adjoining ones, so that the movement of one vertebra by affecting the ribs attached must mean movement of the vertebræ above and below. Finally the intricate fashion in which the ligaments connect the ribs to the vertebræ and the vertebræ to each other must favor concurrent movement in this dorsal region. (Fig. 2.) In agreement with

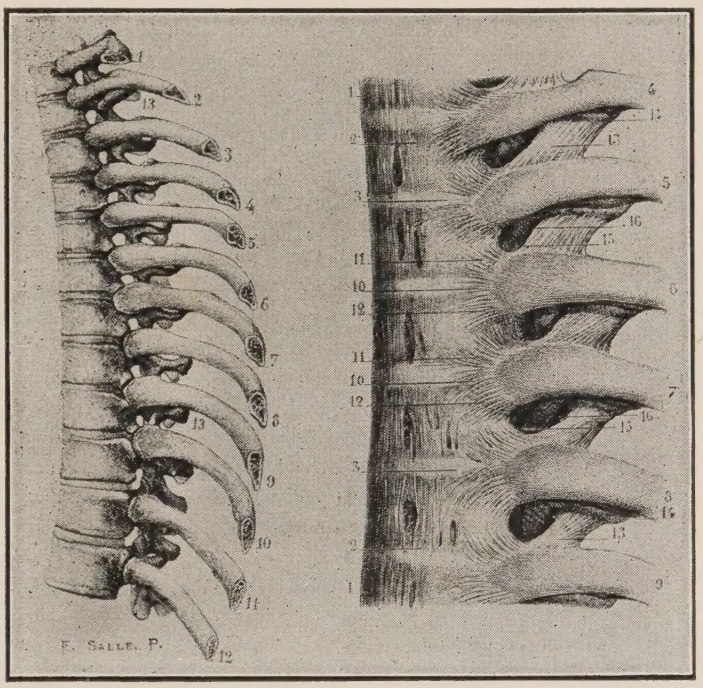

FIG. 2. Sappey's Anatomy. On the left the relation of individual ribs to the dorsal column. On the right the ligaments connecting the ribs with the vertebræ.

the above facts anatomical evidence shows little lateral and antero-posterior motion in the dorsal region (Guerin, Sappey, Quain, Hess) but most of the authorities (Volkman, Lovett, Quain, Schulthess, Menard and Guibal) agree on some intrinsic rotation theoretically possible here. As a matter of fact, however, the chief point at which rotation is carried out is the very lowest dorsal region, for the presence of the thorax interfering with the

individual vertebral movement, it can only take place where the vertebræ have little or nothing to do with the construction of the thorax. These requirements are offered in the region of the 11th and 12th dorsal vertebræ, for the ribs of these two are very short and do not attach to the sternum, they are not connected with the transverse processes of their respective vertebræ, and each is attached to one vertebra only. (Fig. 3.) In the lumbar region there are no ribs to interfere with rotation but the direction of the articular facets makes up for that, so that the only free motion here can be in the sagittal or lateral direction. Moreover

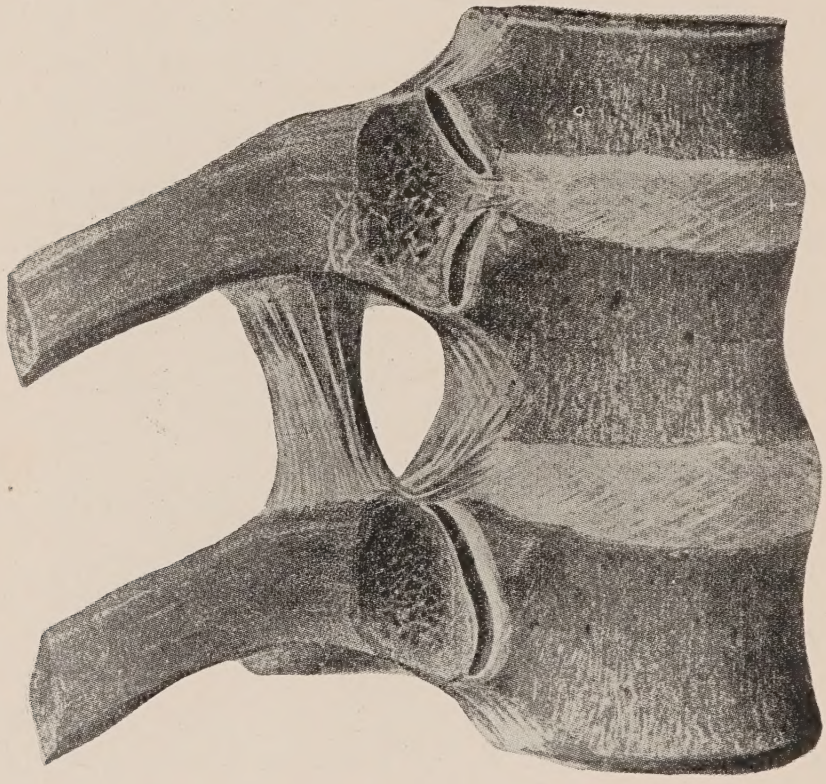

FIG. 3. Fick. The difference between the 10th and 11th ribs in their attachments to the vertebræ.

the change in the direction of the articular facets between the 11th and 12th is very radical for the lower facets of the 12th face like those of the lumbar vertebræ and the upper ones like those of the dorsal vertebræ. (Fig. 4.) This suggests a sudden change of function and we have to do with movement of the dorsal column

rather than movement in the dorsal column. Any individual vertebral lateral or rotatory movement which is possible in the dorsal region, except of course in the region of the 11th and 12th vertebræ, is only that dependent upon such play of the vertebral thoracic joints as is exemplified by breathing, but in breathing we think of a relatively fixed dorsal spine and the walls of the thorax moving in unison upwards and downwards by means of the swinging rotatory play of the ribs at the costovertebral joints.

Even if we assume considerable intrinsic movement in the

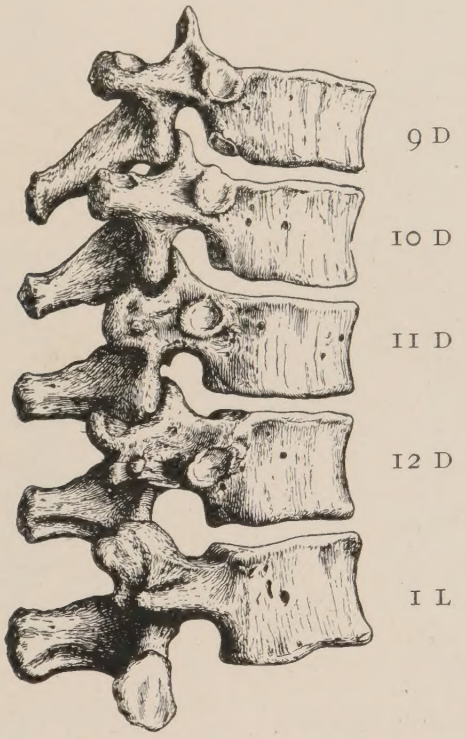

FIG. 4. Quain's Anatomy. 9th, 10th, 11th, 12th dorsal and 1st lumbar vertebræ. Shows the sudden change of direction of the articular facets in the 12th dorsal.

dorsal column, still relatively speaking, we may refer to its segmental motion, and the manner of the thoracic attachment gives this segmental motion a special significance.

THE TRUNK MUSCLES.

In considering the muscles of the trunk we have based our views upon the conception of G. Herman Meyer (Lehrbuch der

Physiologische Anatomie, 1856) who says, "If one leaves out of consideration the presence of the ribs and sternum, then the whole

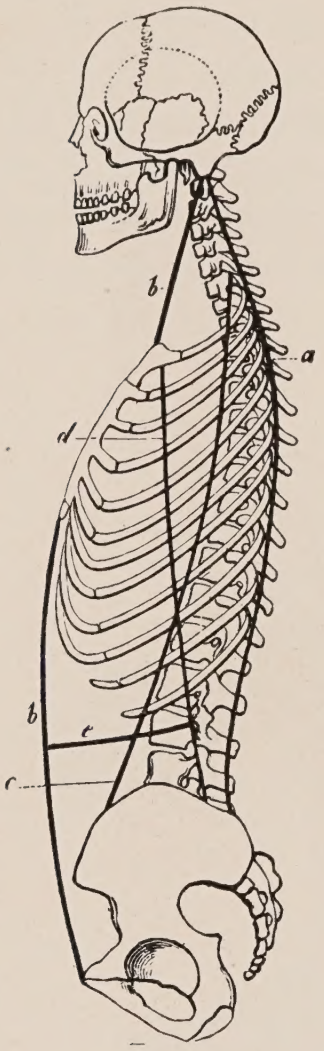

FIG. 5. G. Herman Meyer. The scheme of the trunk musculature indicating the direction of the various muscle pulls. a—posterior longitudinal muscle pull (m. sacrospinalis). b—anterior longitudinal muscle pull. c—oblique descending muscle pull. d—oblique ascending muscle pull. e—transverse muscle pull.

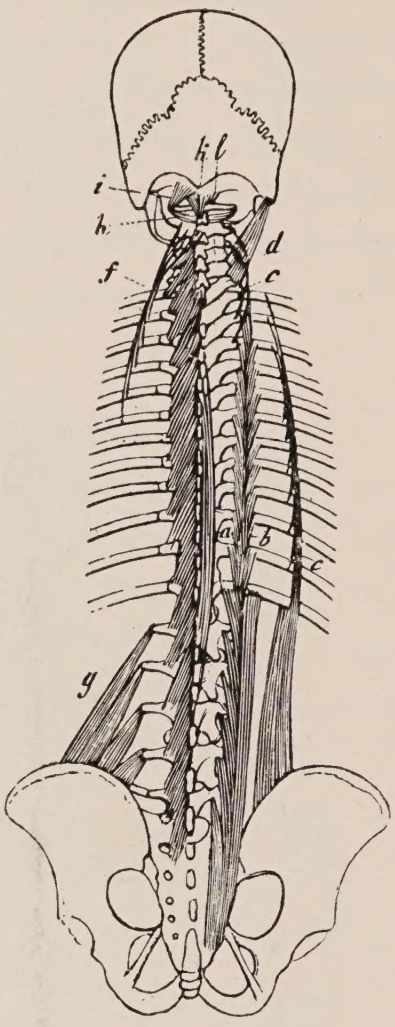

FIG. 6. G. Herman Meyer. The system of the sacrospinalis. a m., spinalis; b m., longissimus dorsi; c m., transversalis cervicis; d m., trachelomastoideus; e m., ileocostalis; f m., ascendens cervices; g m., ileolumbalis (hinder portion of m. quadratus lumborum Auct.); h m., obliquus capitis inferior; i m., obliquus capitis superior; k m., rectus capitis posterior major; l m., rectus capitis posterior minor.

trunk wall is to be regarded as a cylindrical or sac-shaped tube containing the viscera. The muscles which take part in the

fastening together of the same can only have the significance of furnishing a resistance against the pressure of the viscera or that of direct pressure on the viscera. In either circumstance this effect must be such a one as would diminish the tube in its diameter

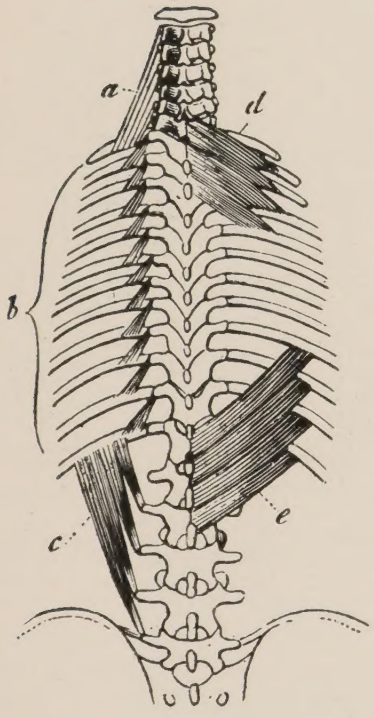

FIG. 7. G. Herman Meyer. The rib muscles. a m., scalenus colli. b m., levatores costarum. c m., scalenus lumborum. d m., serratus posterior superior. e m., serratus posterior inferior.

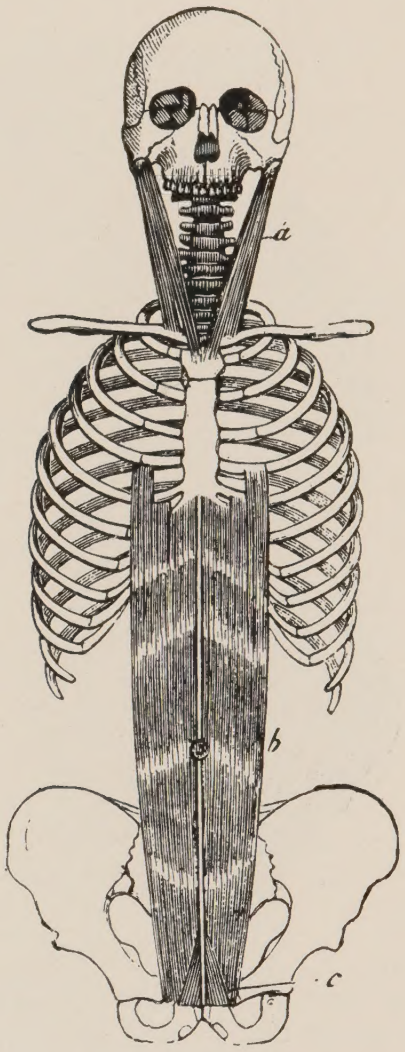

FIG. 8. G. Herman Meyer. Anterior longitudinal muscles of the trunk. a m., sternocleidomastoideus. b m., rectus abdominis. c m., pyramidalis.

and therewith narrow the space present in the same." In using this system he divided the trunk muscles into five groups (Fig. 5). These are the posterior spinal system, the anterior spinal system, the two oblique systems which cross each other, and the trans-

verse system. The posterior spinal system begins at the occiput and ends at the pelvis. (Fig. 6.) In connection with this system we find a close muscular union of the thorax to the spinal column. (Fig. 7.) The anterior system begins in the neck with the sterno-

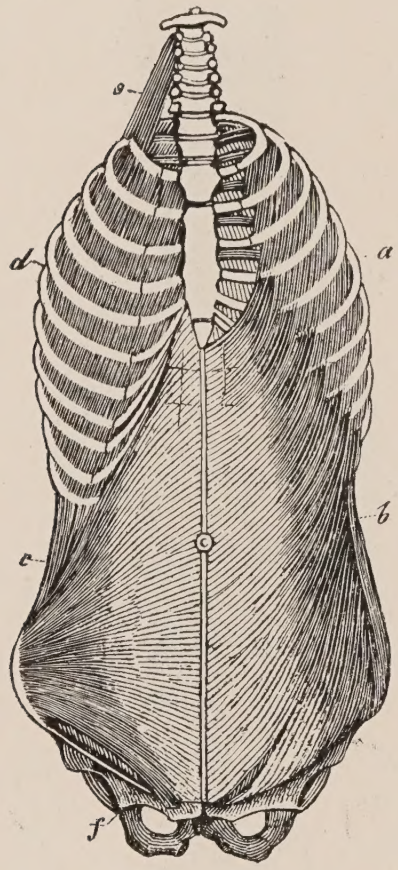

Fig. 9. G. Herman Meyer. The two oblique muscle pulls. On the left the descending oblique. a m., external intercostals; b m., descending oblique or externus abdominis. On the right the ascending oblique muscle pull. c m., descending oblique or internus abdominis; d m., internal intercostals; e m., scalenus colli; f m., cremaster.

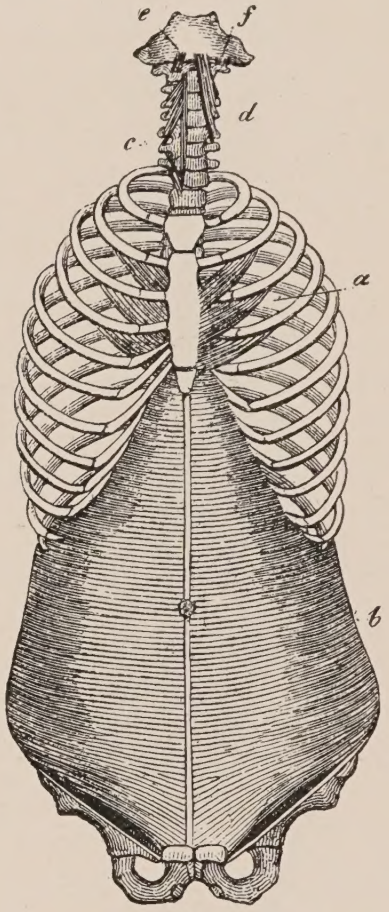

Fig. 10. G. Herman Meyer. The transverse muscle pull. a m., triangularis sterni; b m., transversus abdominis; c m., longus colli; d m., rectus capitis anterior major; e m., rectus capitis anterior minor; f m., rectus capitis lateralis.

cleido-mastoid and is continued from the sternum to the pubis in the shape of the two recti joined by the linea alba. (Fig. 8.) As to the two oblique systems he considers the external inter-

costals as continuous with the external oblique and the internal intercostals as continuous with the internal oblique, the difference in the region of the thorax being simply that the ribs form rigid interruptions. (Fig. 9.) The two pulls cross each other. The transverse system is that of the transversalis muscle which

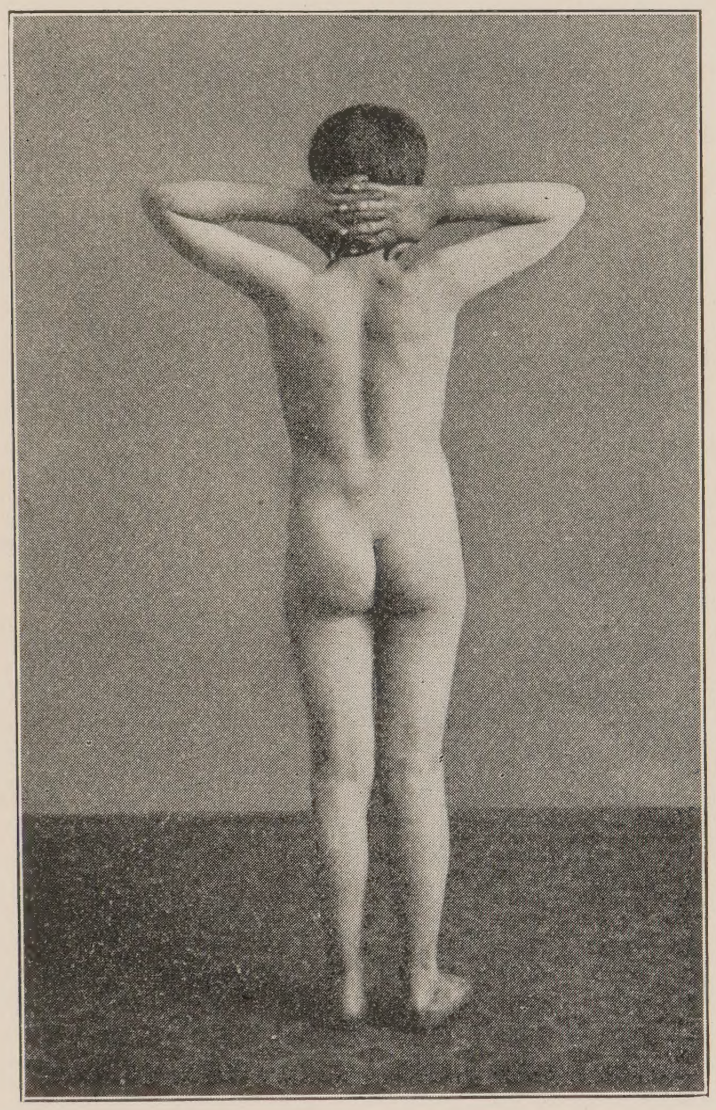

FIG. 11. Normal boy standing erect.

encloses the front of the abdomen and bridges across the subcostal angle. (Fig. 10.)

According to this analysis the muscles of the chest are actually continuous with those of the abdomen, the only difference being the insertion of the rib bones in the upper part, so that the practical

distinction between abdominal and thoracic parietes is merely one of rigidity. Consequently a pull from any part of this tube will not stop at any particular rib, but will always be communicated

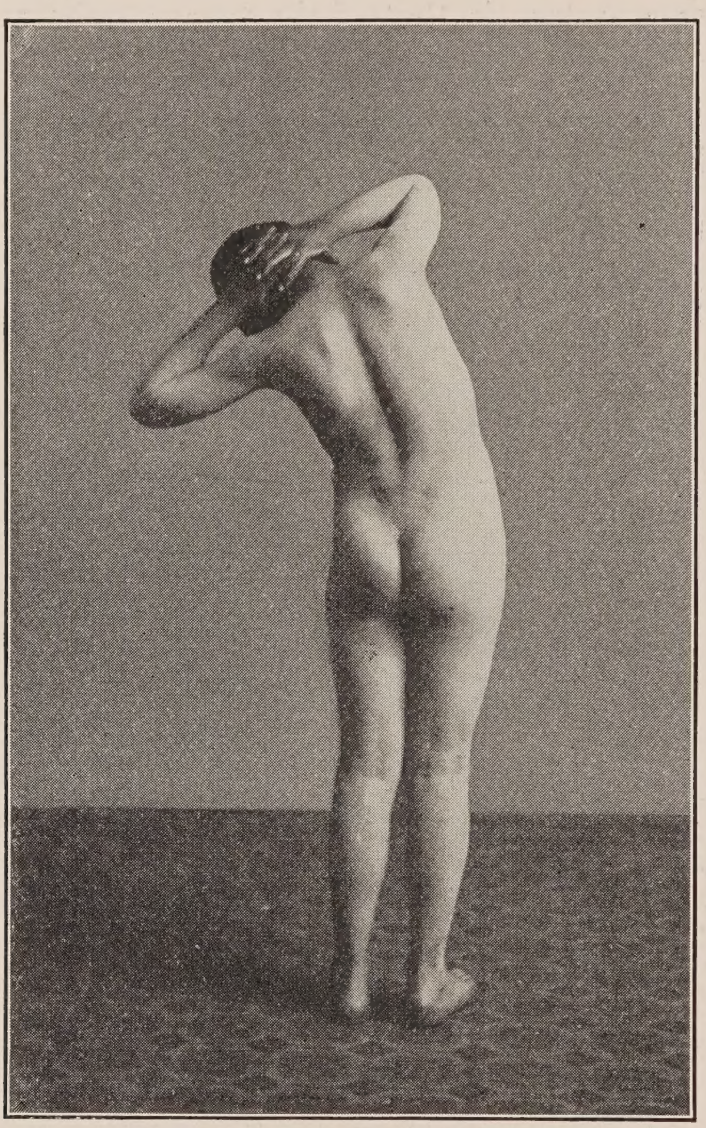

FIG. 12. Normal, bending to left.

to the one above so as finally to exert itself upon the total thoracic wall. (See also Quain, Schulthess, Zuckerkandl und Erben, Duchenne.)

STUDIES ON THE LIVING.

If we seek further interpretation of some of these facts we may resort to photographs of the normal. There are so many varieties

of posture that it is very difficult to pick out any especially important one. A pure bend only occurs by coincidence. In the same way with the pure twist. Nevertheless these two postures are perhaps the simplest for purposes of demonstration. It is to be remembered, however, that the camera only reveals integument-

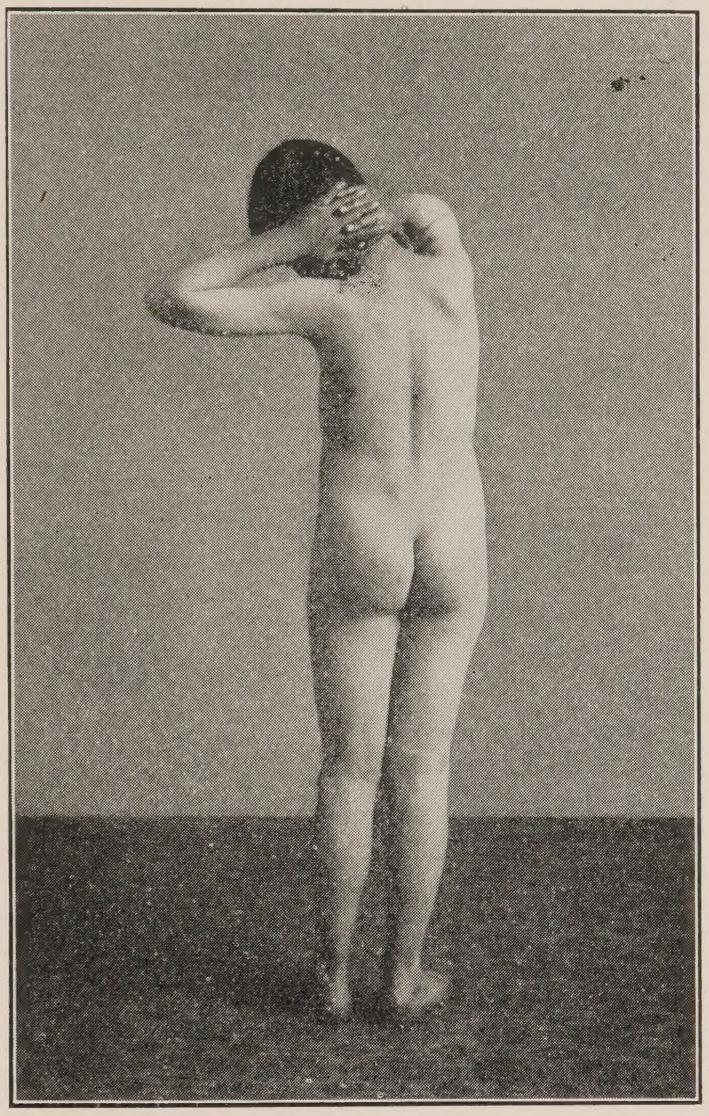

Fig. 13. Normal, twisting.

ary shadows; what goes on under the skin is a matter of interpretation alone.

Fig. 11 shows the normal erect. Fig. 12 shows the effect of a side bend. The segmental movement of the thorax is quite manifest, and it is noticeable that it has swung with its base to the

right until it meets the resistance of the lateral factors. The hips are also swung to the right and so also are the knees. The right side of the body is drawn hard and tight, while the left is in folds. In this case which is one of almost pure lateral flexion a sharp bend is noticeable at the dorso-lumbar region. Of course if the

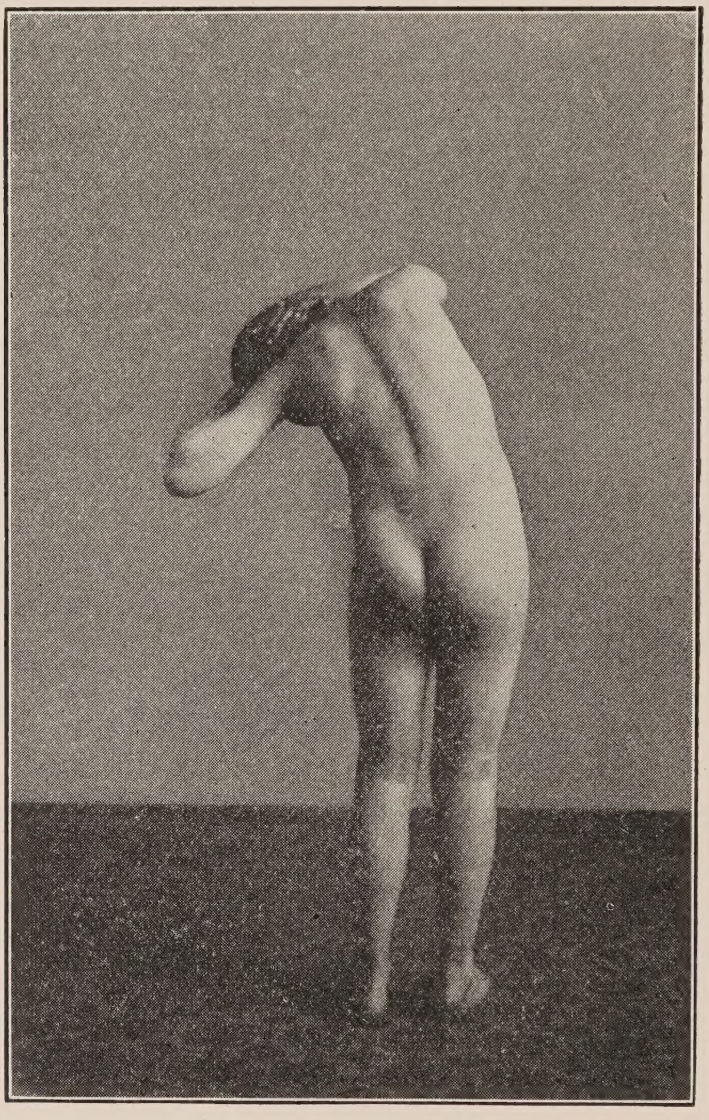

FIG. 14. Normal, bending sideward and forward and slightly twisted.

point of view had been somewhat to the left, there might have been some apparent dorsal curve. The tension on the right thoracic wall is a direct one, taking place on diametric opposition to the bending column and increasing in proportion to the bend. Fig. 13 represents the twist. The twist begins from the ankles,

includes the pelvis, and finally the thorax and shoulders. The soft parts connecting the thorax with the pelvis have become spirally tense. This tension has rotated the pelvis and even affected the knees, showing that the action is communicated from

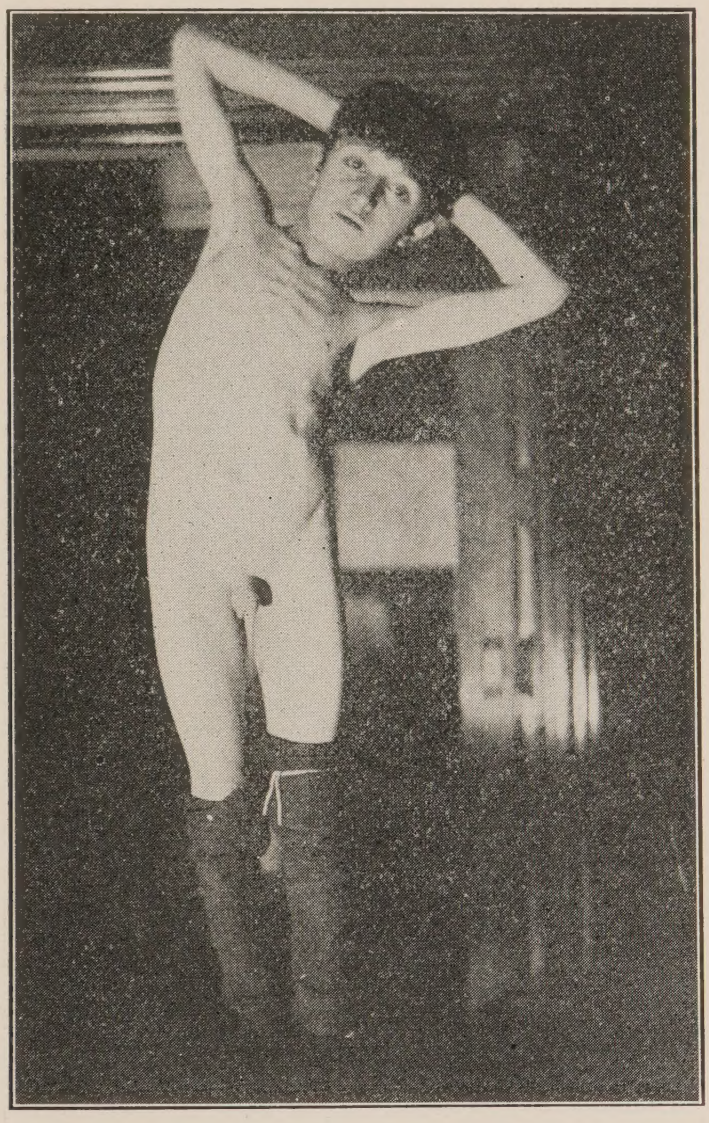

FIG. 15. Normal from in front bending laterally.

one segment to the other. The tension on the thorax, however, is not a direct one like in lateral bend, for the two forces, the resistance in the ribs and the tightening of the tube, do not diametrically oppose each other. Fig. 14 shows the effect of forward

and lateral bend with a slight twist, giving the dorsal region an apparent lateral curve. The right pelvis is raised by means of the tightly drawn factors running from the thorax, and the length of the body is greater on one side than on the other. Again the right thoracic wall is under strain. Fig. 15 shows the effect of

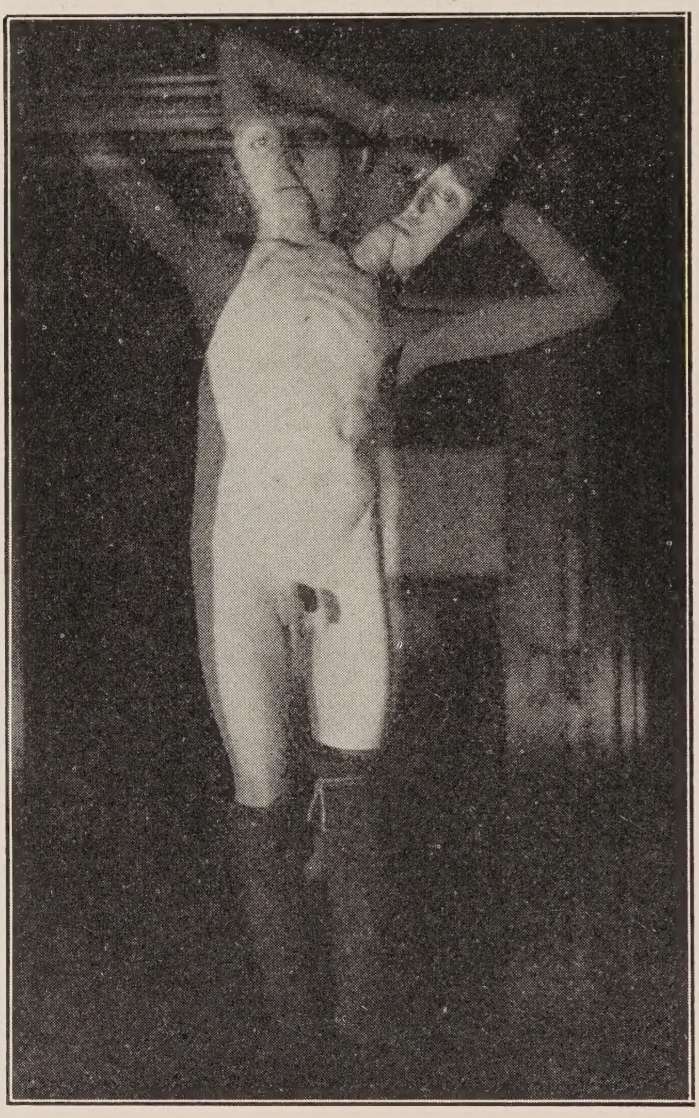

FIG. 16. Composite of erect and lateral bend.

lateral bend from the front in another boy. The noticeable thing is the pendulum movement of the thorax, swinging as a segment within the tube of tissues with its base to the right and its apex to the left. This being a position of equipoise, segments are balanced over the base of support. Fig. 16 is a composite picture

after the method of Lovett, comparing the lateral movements in the previous figure with the erect without changing the foothold or camera. This figure shows the lengthening of the body on the right implying the increased tonicity of the muscles, and as

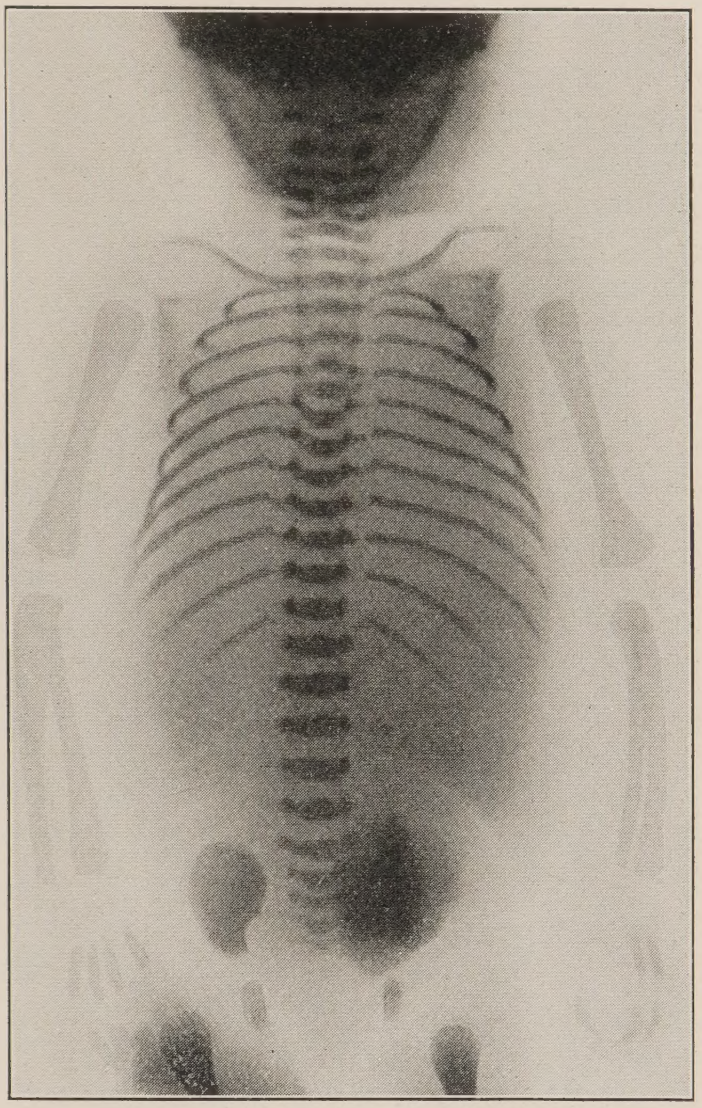

FIG. 17. Röntgengram of fetus laid straight.

Lovett points out the part taken by the entire body in a lateral bend. (Compare with Lovett, Guerin, Volkman, Weber Brothers.)

RÖNTGEN STUDIES.

Fig. 17 shows a fetus laid straight on the negative. It happened that the thoracic cavities were not quite equal in breadth, the

right being smaller than the left. Fig. 18 shows the effect of bend to the right. The tension on the wall is so great that the left thoracic cavity, which beforehand was broader, is now become narrower than the other, for the tube of tissues running from the neck to the pelvis on that side being lengthened, is so stretched that the strain coming on the ribs has approximated the side wall

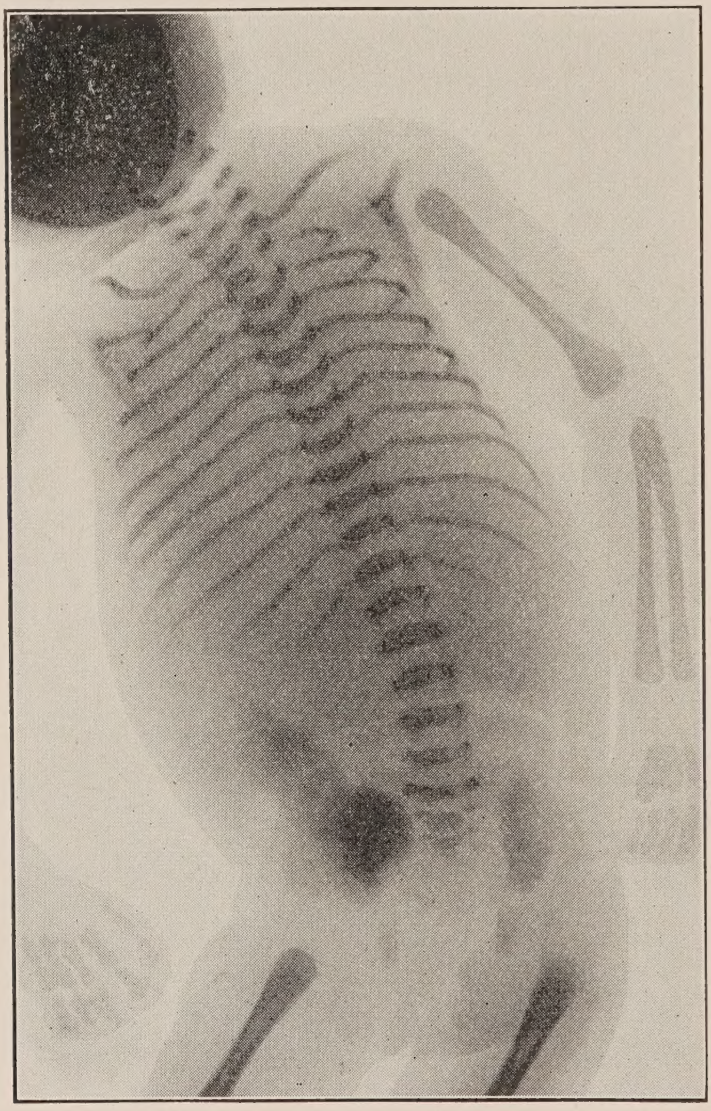

Fig. 18. Röntgengram of fetus bent sideways.

to the vertebral column, also it has caused the ribs on that side to separate and to descend, while on the opposite side they are more crowded together. Fig. 19. Twist. The relative distortion in taking such a picture is so difficult to measure that it is

not fair to estimate the size of the thoracic cavities, but the thing which is plain is that the tube of tissues does have at least a little effect upon the bony thorax. Fig. 20. This is a Röntgen picture of a three year old normal living child. The effect here is similar to that seen in the fetus in side bending—namely, narrowing of

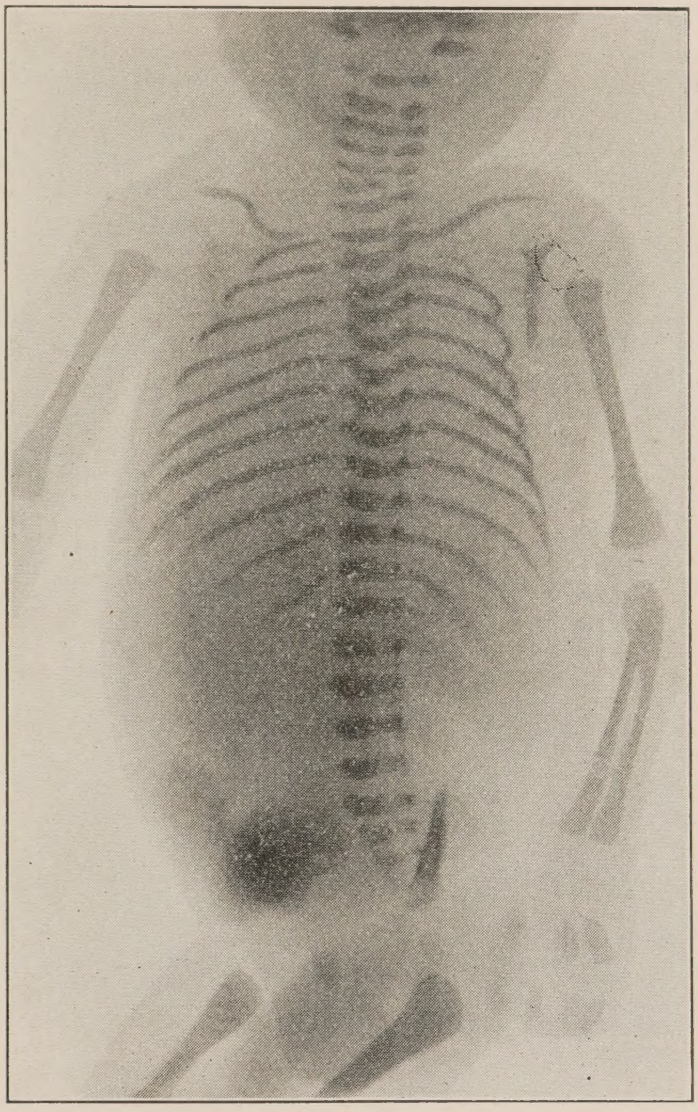

FIG. 19. Röntgengram of fetus twisted.

the thorax on the convex side and separation and descent of the ribs, and crowding on the other. There seems to be some lateral bend in the dorsal column. This is at least partly due to the slight twist accompanying the bend. The maximum bend is however in the lowest dorsal region. Fig. 21. The effect of

side bending in a ten year old living boy, and the same effect is once more to be demonstrated.

Conception of Artists.

The expression of thought which stands on the highest plane is that conveyed by great artists, but we present the following cuts

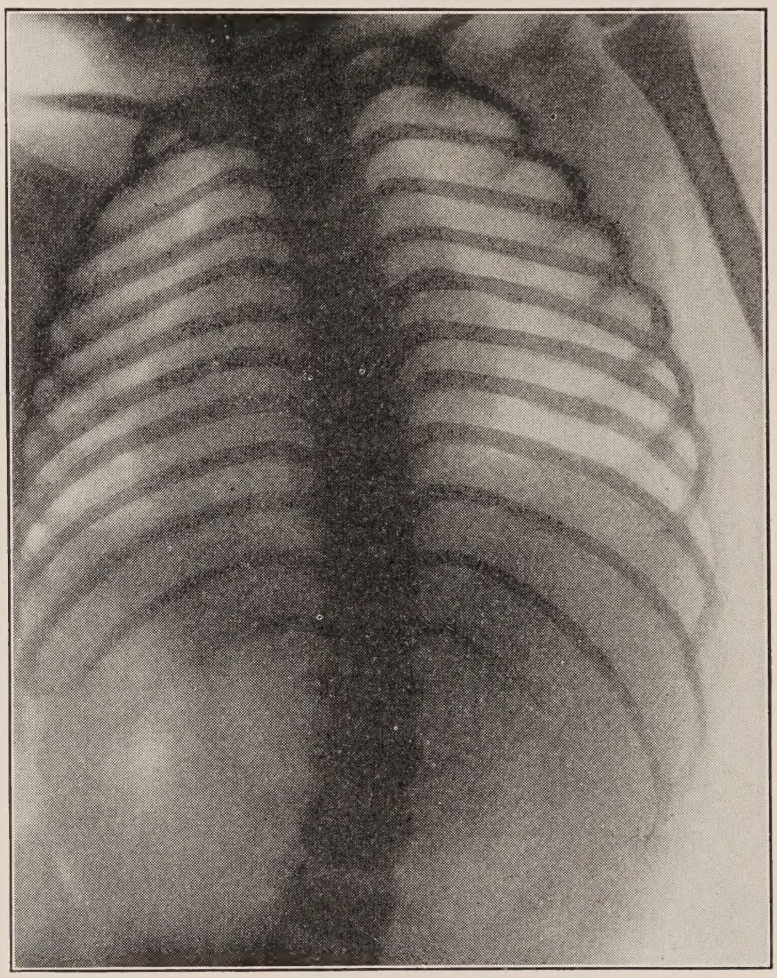

Fig. 20. Röntgengram of three year old living child bent to side.

here less for their scientific value than as a matter of appropriate interest. The artist first conceives and then expresses, and this expression depicts not merely what he observes, but what he thinks, and if he sees no deeper than the skin, yet he tries to realize what is going on beneath. Then by accenting certain contours and shadows he may give us his thought. No camera can do this.

We have first to do with those artists who studied the physiology of motion chiefly from the living. These were the Greeks, who, having dissected little or not at all, nevertheless gave much time and thought to the human physique, as seen in athletic sports (Duval, Fletcher). Then we have to do with the later schools who based their conceptions, at least to a moderate degree, on their

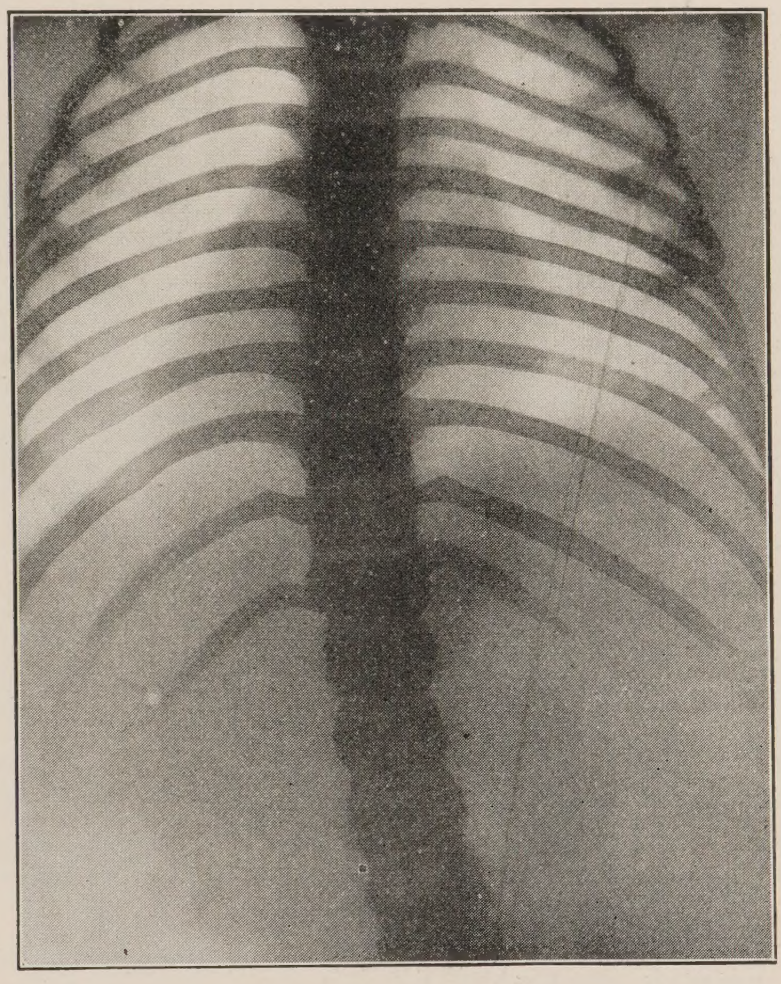

FIG. 21. Röntgengram of ten year old living boy bent to side.

knowledge of anatomy. This group is represented chiefly by Michaelangelo and Raphael, who made great use of their anatomical knowledge. (Critical essays of masters, Ruskin.) Leonardo DaVinci besides his vast anatomical learning made a careful study of the mechanics of motion and posture. (Leonardo DaVinci—Munz's edition, Richter's edition. Extracts from Leonardo's works.)

Fig. 22 from eastern pediment of Parthenon. Postural figure reclining on left thigh and pelvis. The trunk is bent upwards. The thorax is moved as a whole. The left lateral wall of the torso is in a state of extreme tension, straining the left thoracic wall and compressing its sides. The right wall of the thorax is not compressed and even flares out. The mid-thoracic line is practically straight but continuous with the mid-abdominal line.

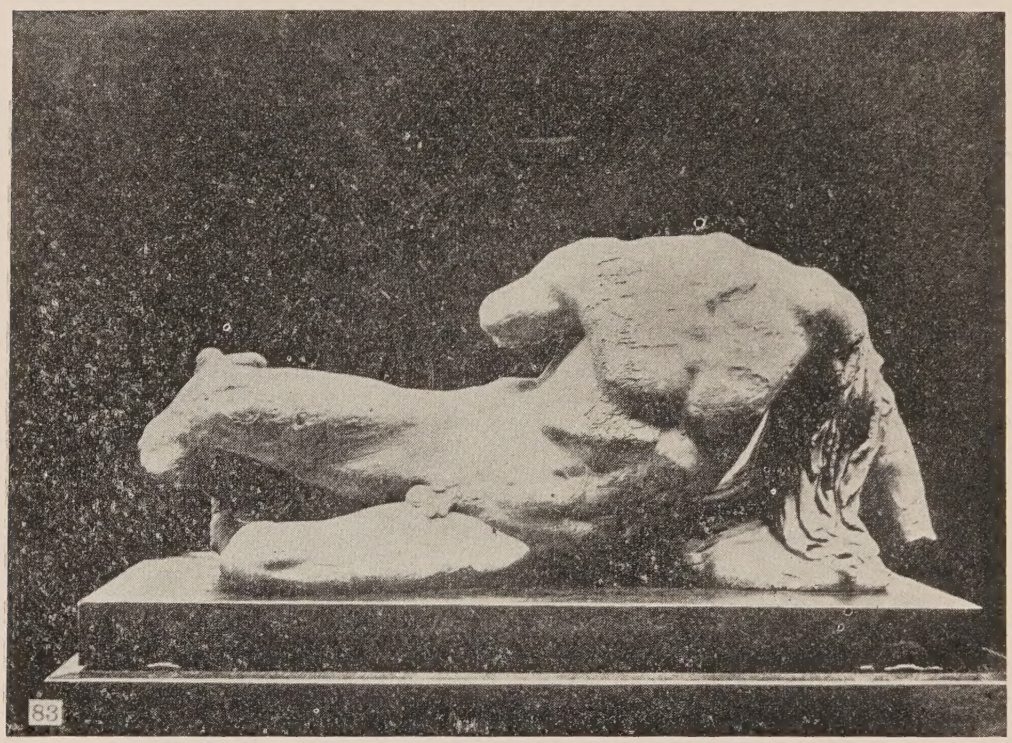

FIG. 22. Figure from Eastern Pediment.—British Museum.

Fig. 23. Laocoon. Middle figure in action. Torso bent to left. Thoracic segment bending as a unity, but with such force as to cause great strain on right thoracic wall. Left trunk shows a fold at the waist line.

Figure of boy in the right of the picture in strained posture. Thorax bent to the left. The strain is upon the right thoracic wall beginning at foot. The waist at the left thrown into folds.

Fig. 24. Farnese Hercules. Postural. The figure rests partly

on support. The thorax has shifted to the left. In this figure the left chest is under pressure and the right is relaxed. The mid-thoracic line is straight and at the ensiform the linea alba diverts from this towards the pubis showing the shifting of the chest as a unity.

The Wrestlers. Fig. 25. Figure on top in action. Trunk

FIG. 23. Laocoon.—Vatican.

bent forwards and thorax twisted, facing to the right. The thorax here has twisted considerably with respect to the pelvis. The total segment has bent and yet the line representing the spinous processes is continuous in a total curve with the lumbar spinous processes. The factors which are thrown into tension are

those on the right. From the shoulder to the buttocks the whole right chest is under compression owing to the tension. The left waist shows two folds of relaxation. Ribs here are not compressed.

Sketches by Leonardo DaVinci. Fig. 26. The figure in equilibrium and activity. Weight resting on right foot. The

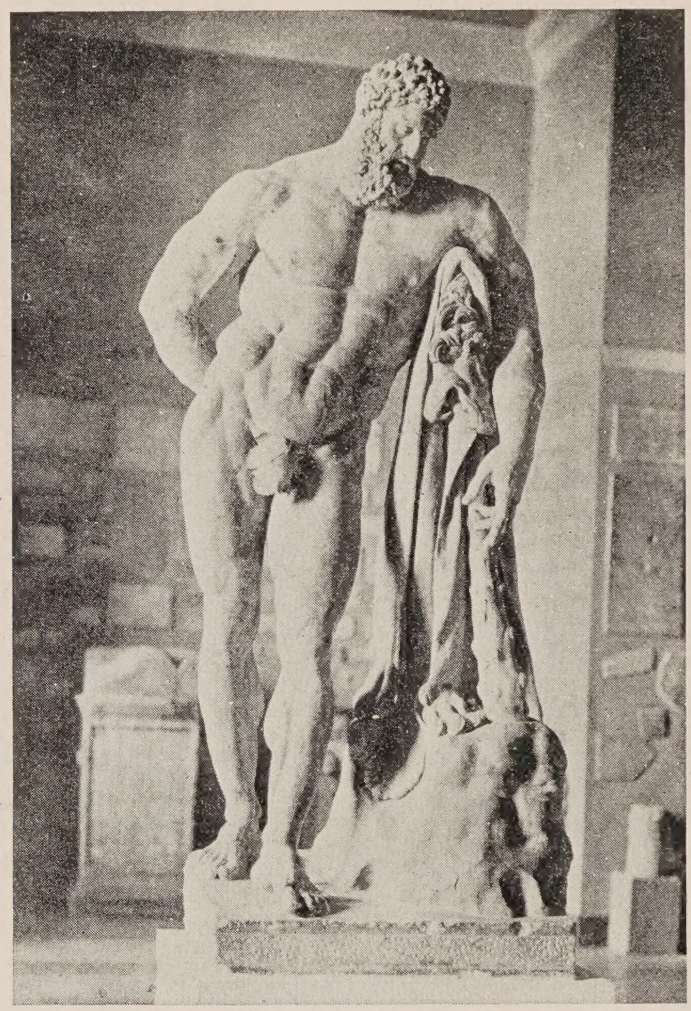

Fig. 24. Farnese Hercules.—Vatican.

line of balance passes through upper part of thorax. Trunk bent to right. Right waist line folded and left side of torso in comparative tension. Fig. 27. Figure on left. Postural. Facing forwards. Weight on left shoulder conveyed into right foot. The thorax bent towards the right, its lower border swinging to the left, throwing into tension the left wall and relaxing the right

waist line. Figure on right. Weight on back conveyed through left foot. Tension doubtful on account of weight-bearing. In both figures the line of balance passes through the pit of the neck. Fig. 28. Figure on left. Figure twisting to the left. Right trunk wall taut. Left waist free. Figure on right. Twisted to the left and bent to left. Right shoulder high. Right and anterior

FIG. 25. The Wrestlers.—Uffizi.

trunk wall tight, apparently compressing right thorax. Left waist in folds. Fig. 29. Postural figure. The line of balance passes through the pit of the neck and weight resting on the left foot and left hip. Trunk bent to the left. Lower thoracic wall swung to right so that the right thoracic wall is under tension, while the waist is folded on the left. The arc from the pubis

to the pit of the neck represents the arc of the folds radiating from an imaginary center to the left of the figure. Fig. 30. Figure in activity. Line of balance through pit of neck. Figure rests

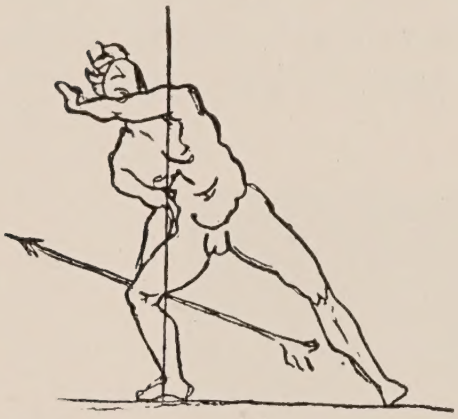

FIG. 26. Sketch by DaVinci. Trattato della Pittura.

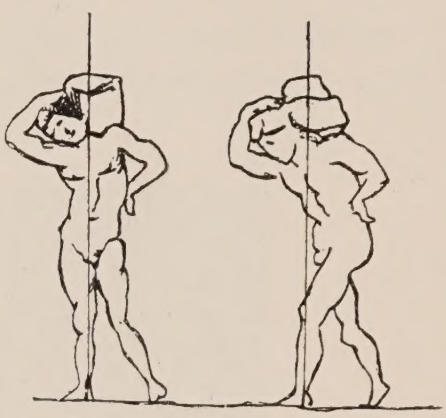

FIG. 27. Sketch by DaVinci. Trattato della Pittura.

on right foot and is twisted to the left. Both trunk walls under tension. Fig. 31. Dancing figure. Line of balance passes

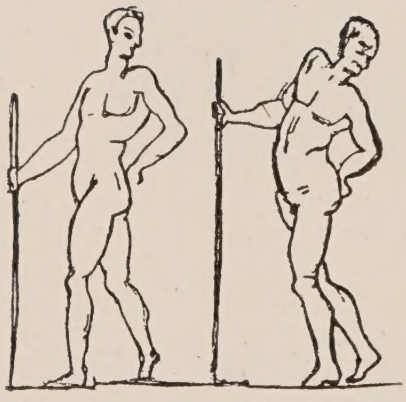

FIG. 28. Sketch by DaVinci. Trattato della Pittura.

FIG. 29. Sketch by DaVinci. Trattato della Pittura.

through pit of neck. Trunk bent to right and right waist in folds, while left trunk wall is greatly tightened from the foot to

the shoulder. Fig. 32. Postural figure. The line of balance through pit of neck. Resting on right hip and right foot. Left torso wall tight. Right waist concave. Thorax swung to left.

FIG. 30. Sketch by DaVinci. Trattato della Pittura.

FIG. 31. Sketch by DaVinci. Trattato della Pittura.

Fig. 33. Dancing figure. Great twist of thorax to the right showing great tension on all thoracic walls.

Michaelangelo sketch. Fig. 34. Figure with back. Shows

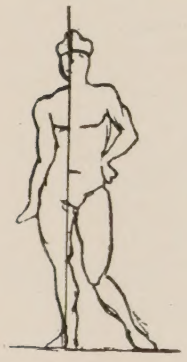

FIG. 32. Sketch by DaVinci. Trattato della Pittura.

FIG. 33. Sketch by DaVinci. Trattato della Pittura.

weight thrown on right hip and right foot. The head over right foot. Trunk bent to right from the pelvis. Thorax swung to left. Tightening of left trunk wall throwing right waist into folds. Although the thorax has moved as a whole the mid-spinal furrow has an apparent left lateral curve.

Fig. 35. Raphael. Figure on right. Weight on left foot. Head poised over this. Trunk twisted to the right but bent slightly backwards. Thorax conceived as a total thing. Left waist line considerably relaxed.

Fig. 36. Stuck. Compare with Michaelangelo's sketch.

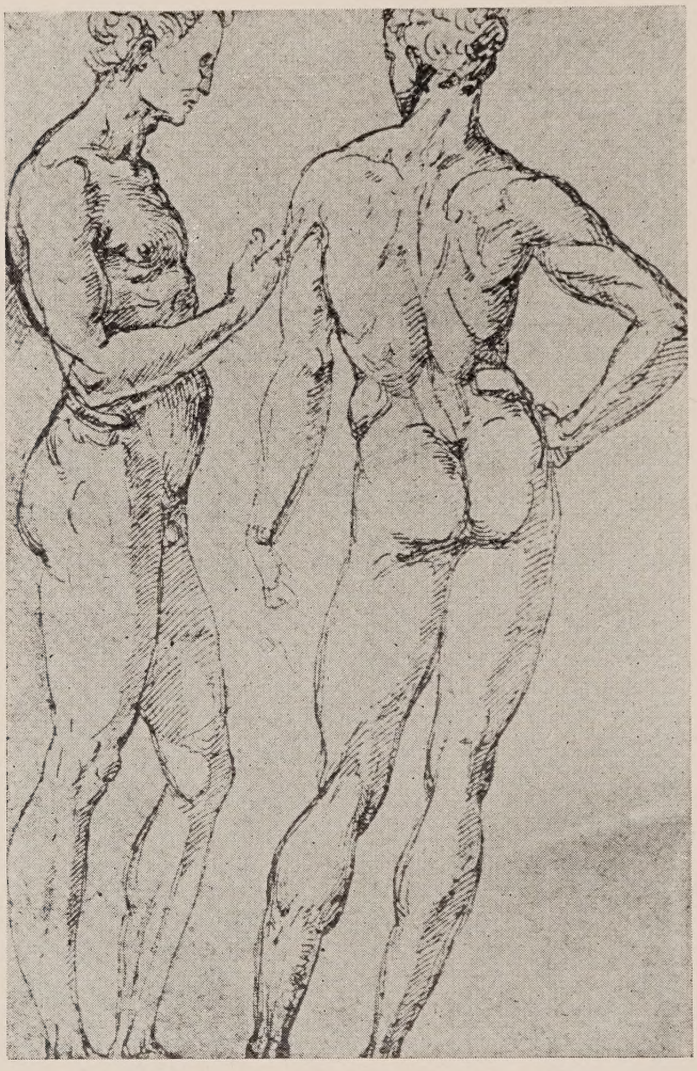

Fig. 34. Study by Michaelangelo.

Thorax here shifted as a total segment upon the pelvis showing tension on left thorax wall and fold at right waist line. The lower border of the thorax has swung to the left.

General Conclusions.

The Effect of Movement on the Soft Parts.

The muscular system, the fasciæ and the skin forming an

enveloping layer from the neck down to the pelvis, any movement of the trunk must throw a part of this enveloping tube into tension. If, for example, the pelvis is fixed and the trunk bent to the side, then whatever be the primary source of movement, the convex side of the enveloping tube is immediately tightened by the mechan-

FIG. 35. Study by Raphael.

ical conditions of separation of the parts. Again if in equipoise posture the head is kept in the same relative position to the feet and the body bent to the side, it must imply a folding of the tissues on the concave side and a tension on the other side of all the factors running from the foot to the head.

In a twist, the enveloping tube running from the thorax to the pelvis is strained spirally until it is taut, the pelvis coming

with it until brought to a standstill by the muscles, fasciæ and ligaments which hold it to the thighs. The thighs and legs being fastened together by the stiffened knee-joints come still further

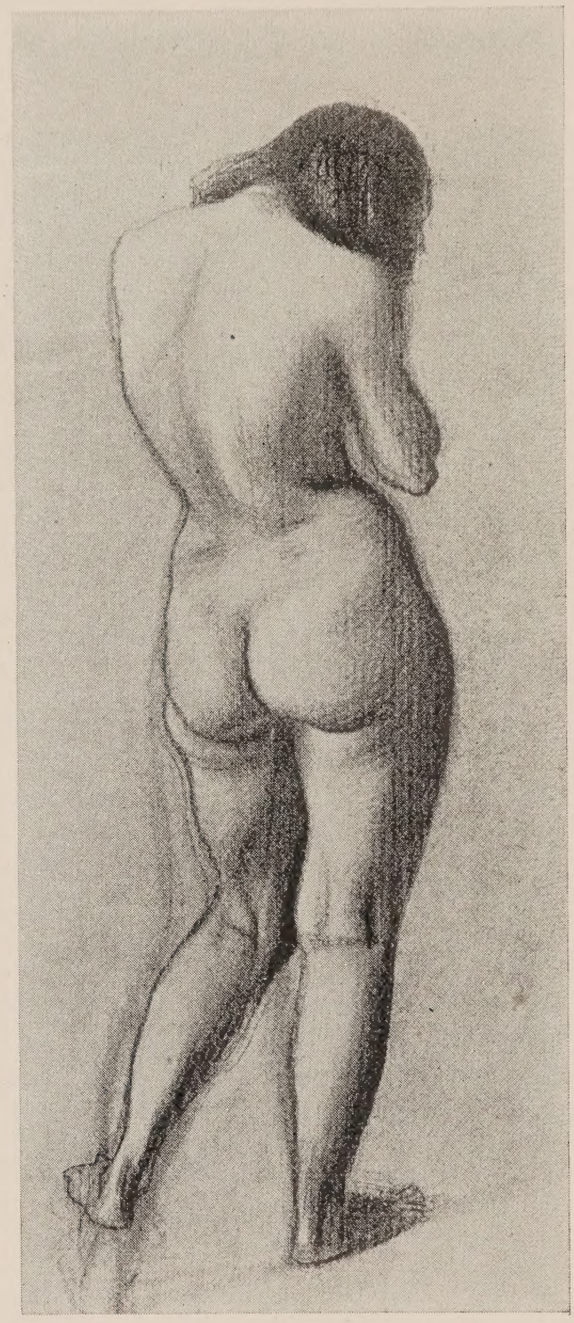

FIG. 36. Study by a recent painter. (Stuck.)

around on the ankles until the ligaments, muscles and fasciæ around these joints are made firm, so that whatever motion is made and whatever the cause of motion, there is always an element of tension in the soft parts which connect adjacent segments.

Effect on the Thorax.

In the thorax the greatest tension must come upon those factors to which this segment owes its maintenance of shape, namely, the ribs. In a side bend the tissues running over the thoracic wall on the convex side are immediately stretched, so that if there is any elasticity in the rib wall they will first give on that side. For as the body lengthens here the muscle wall will tend to approximate the bending column, and the more so in a position of equipoise, which would imply a pendulum motion of the thorax, its base swinging to the side of the convexity. This approximation of the side wall to the column is the important thing, for this means a direct strain upon the interposed rib wall, namely, the posterior part of the thorax in question. The tendency which follows would be for the angles of the ribs to become sharpened on that side. Besides this, on account of the stretching of the lateral wall, the ribs will separate in accordance with the amount of tension, and there will be a downward inclination compared with the ribs on the other side. On the side of the concavity the ribs become crowded together and there is no tendency to sharpen their angles.

In a twist the strain of the muscular resistances is transmitted through the circumference of the base uniformly so that the strain comes upon both halves of the thorax at approximately the same time. This would of course tend to a separation and a descent of the ribs on both sides. The separation of the base of the thorax from the pelvis is not of the same mechanical character as that in lateral bend, for in a lateral bend the direction of the tightening is diametrically opposed to the maintenance of shape of the thorax, while in twist, although the strain may come just as quickly, its direction is not directly antagonistic to the tendency to maintain the shape. Nevertheless there must ultimately be a great strain on the side walls of the thorax as the twisting column drives it through and against the resistances of the encompassing tube and the rows of ribs must tend to change their shape under the strain, although on account of the uniformity of the strain, actual change of shape may be little apparent.

The Effect on the Column.

If the ribs are under strain the effect of this strain must be further communicated to whatever is attached, namely, in this case back into the spinal column. Although the tendency to rib distortion is clear, the effect in the column itself cannot be easily demonstrated on the dead or on the living. In the dead, dissection is necessary, which destroys the normal conditions. In the living the bodies of the vertebræ are too far beneath the surface to permit accurate study. The Röntgen ray meets its limitation on account of the distortion, due to the fact that the rays come from one point. We therefore, will attempt to figure out the effect deductively and on a mechanical basis.

In the first place the region of the connection between column and ribs is the bow of arches and the posterior parts of the bodies of the vertebræ (Fig. 1) and it is in this region that the effect of potential strain on the ribs must first be communicated. The important fact in a side bend is the approximation of the convex wall of the muscle tube to the spinal column or the reverse, tending to narrow that side of the body, so if in side bending the convex thoracic wall comes under strain and this strain is communicated from the ribs back into the spinal column at its posterior part, the row of arches, then while the ribs are sharpening and separating on that side, they must be conveying the strain into the posterior part of the vertebræ, so that this part will naturally tend to give in the direction of the strain; and the spinous processes are pushed in one direction while the fronts of the bodies of the vertebræ are approximating the bent wall in an opposite direction. In other words, while the total dorsal column is moving as a part of the thoracic segment, the strain brought to bear on the ribs is communicated back into the posterior part of the column as a separate tendency of reaction. This reactionary tendency in the column which we may designate as retrograde, is again counteracted in the normal by the firm connection of the anterior and posterior spinal ligaments, and by the inherent tendency of the dorsal column to maintain its unity.

In twisting the principles are the same but the effect is less direct. As a person twists, the soft parts running down the sides

of the thorax at the pelvis tighten, but tighten in a direction which is not directly opposed to the maintenance of shape of the thorax, so that we may not note any special local effect upon the thoracic walls. Nevertheless whether the actual shape changes much or not, the ribs do eventually come under strain and in the column itself this strain must fall once more upon the posterior part. Therefore, while the dorsal column is moving primarily with the segment of the thorax, its posterior part must tend to travel in a direction necessitated by the potential strain of the ribs, and this retrograde tendency, as in lateral bend, meets its resistance simply in the cohesiveness with which individual vertebræ are bound together.

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